VERSATILE ANALOG INTERFACE FOR YOUR COMPUTER

Build this simple device to allow your computer to look at the outside world—without complex analog-to-digital conversion.

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INTERFACING AN ANALOG RESISTOR-CAPACITOR NETWORK TO A digital microprocessor has a wide variety of real-world applications. With this interface and the proper software, you can use the microprocessor to measure the time constant of a resistor-capacitor combination. This concept suggests numerous potential applications, including joysticks, a capacitance meter, proximity switches and more.

The circuits in Figs. 1, 2 and 3 use a minimum of components and a software timing loop to measure the value of the R–C network. A single IC allows you to build up to six of any of the circuits described here. Although this article describes 8080 and BASIC software, adapting the interface to any other type of microprocessor and software processor should be easy.

How it works

All circuits essentially consist of a resistor-capacitor network at the input of any one of the six non-inverting buffers in IC1. When the input of the buffer is low (at ground potential), the output is also low. As the voltage across the capacitor rises above approximately 3, the output changes to a logic high level. The resistor that charges the capacitor is connected to one bit of an 8-bit output port. The output of the buffer is connected to the corresponding bit on an 8-bit input port. Up to eight circuits could be implemented by one 8-bit input port.

Construction

The easiest way to build this circuit is on a small piece of perforated board. We recommend providing a socket for IC1. A small transistor socket works well to hold capacitor C_x (see Fig. 2). Component layout is not critical. The capacitor tester (Fig. 2) works best with a fairly stable +5 V_{cc}, but this is not at all critical in the other circuits.

Software

The real workhorse of all these circuits is a machine-language program called CVAL (see Listing I). The first line of this CVAL routine has a variable called BIT#. Setting one of the eight bits in BIT# to a logic high with the rest set to a logic low level determines which bit of the I/O port to test. Since my sample circuits are connected to the least-significant bit, I set the LSB of BIT# to logic high level by setting BIT# equal to 01 (hexadecimal code). The routine then sets its counter (register-pair HL) to 0. The routine now outputs a logic high to the selected circuit and begins counting. When the buffer output finally goes high, the routine stops counting, outputs a logic low to the circuit, and returns to the calling program with a value in register-pair HL that is equal to the time constant of the resis-

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                    LISTING I.
ORG 04400H                    ;PROGRAM OUT OF THE
                              ;WAY OF BASIC IN LOWER
                              ;MEMORY

CVAL:   MVI E, 01H*           ;MOVE BIT# TO REG. E
        XRA A                 ;A = 0
        MOV H,A               ;H = 0
        MOV L,A               ;L = 0
        MOV A,E               ;A = BIT# TO BE TESTED
        OUT 01H               ;TURN ON SELECTED BIT
GO:     INX H                 ;START COUNT
        IN 01H**              ;CHECK INPUT PORT
        ANA E                 ;MASK ALL BUT BIT#
        JZ GO                 ;JUMP IF BUFFER NOT ON
                              ;YET
        XRA A                 ;A = 0
        OUT 01H**             ;TURN BIT# OFF
        RET                   ;RETURN TO CALLING
                              ;PROGRAM
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LISTING II

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MAIN:    LXI SP, 04800H   ;SET STACK POINTER
                             (ROUTINE STARTS HERE)
         XRA A             ;A = 0
         OUT 01**          ;OUTPUT 0 TO ALL
                             CIRCUITS
         OUT 0BH**         ;SWITCH OUTPUT = OFF
         MOV D,A           ;SWITCH STATE REGISTER
                             = OFF
ONYET:   CALL TDM          ;SHORT TIME DELAY SO
                             CAPS DISCHARGE
         CALL SWON         ;SWITCH BEING TOUCHED?
         CPI 01            ;SEE IF A = 1
         JNZ ONYET         ;CHECK AGAIN IF NOT
                             TOUCHED YET
         XRA D             ;A = 1, EXCLUSIVE OR
                             WITH SWITCH STATE
         MOV D,A           ;D = NEW SWITCH STATE
         OUT 0BH**         ;OUTPUT NEW SWITCH
                             STATE IN LSB PORT 013
OFFYET:  CALL TDM          ;PAUSE FOR DISCHARGE
                             AGAIN
         CALL SWON         ;SWITCH STILL ON?
         CPI 01            ;CHECK
         JZ OFFYET         ;JUMP IF STILL ON
DBLCHK:  LXI B, 04000H     ;B = 20H, C = 0
         CALL DEC          ;LONGER TIME DELAY TO
                             DEBOUNCE SWITCH
         CALL SWON         ;SWITCH STILL ON?
         CPI 1             ;CHECK
         JZ OFFYET         ;TRY AGAIN IF IT IS
TOUCH:   MOV D,A           ;A = 0, SWITCH STATE =
                             OFF
ONLY:    OUT 0BH**         ;TURN SWITCH OFF
         JMP ONYET         ;CHECK FOR NEXT TOUCH
SWON:    CALL CVAL         ;GET ACTUAL TIME
                             CONSTANT
         MOV A,L           ;GET LOW ORDER BYTE OF
                             CONSTANT
         CPI 0BH***        ;COMPARE WITH MINIMUM
                             ON VALUE
         JP ON             ;IF IT IS GREATER SWITCH
                             IS ON
         XRA A             ;ELSE MAKE A = 0 TO
                             SHOW IT IS OFF
         RET               ;THEN RETURN
ON:      MVI A, 01         ;MAKE A = 1 TO SHOW IT
                             IS ON
         RET               ;NOW RETURN
TDM:     LXI B, 0100H      ;B = 01, C = 0
DEC:     DCR C             ;DECREMENT C
         JNZ DEC           ;C = 0?
         DCR B             ;DECREMENT B
         JNZ DEC           ;JUMP IF BC = 0
         RET               ;TIME DELAY ALL DONE
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Notes: My origin statement sets this program in the 18th K of memory (04400H). This gets it out of the way of my basic interpreter in the first 13K. Of course it may be relocated and run anywhere in memory.

* —BIT #. This variable has one bit high to determine which bit of the I/O port is to be tested.

** —Port numbers specific to my system. May be changed to fit whatever ports are free.

*** —Minimum on value. If CVAL reads a value less than this SWON will return, indicating switch is off. This value deterines the sensitivity of the touch switch.

8080A mnemonics are used throughout. BASIC is Digital Group Maxi-BASIC Ver. 1.0.

tor-capacitor combination. After a short time, the capacitor discharges through the resistor and is ready to test again.

Applications

The device shown in Fig. 1 (driven by Listing II and CVAL) is a simple touch or proximity switch. To start the routine, jump to line **MAIN**. This assumes the switch is connected to the least-significant bits of IN 01 and OUT 01 ports (port numbers are specifically geared to my system), and it outputs the state of the switch in the LSB position of OUT 0BH port (0= OFF; 1=

ON). As shown, the program simulates a normally open momentary contact switch. Delete (or insert NOP's) lines TOUCH and ONLY, and the routine simulates a touch-on/touch-off switch. The routine operates by calling CVAL, and seeing if the result is greater than a byte called "minimum on value." The value I show for this is 0B (hexadecimal), which works for the value capacitor shown in Fig. 1 and a fairly positive contact of the touchplate. Lowering this value increases the
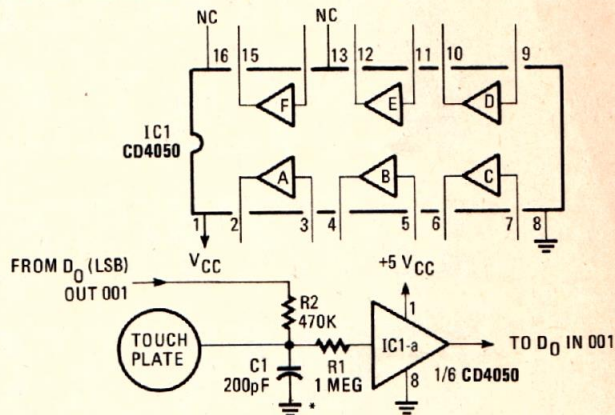

* SYSTEM SHOULD BE GROUNDED TO EARTH GROUND FOR TOUCH SWITCH APPLICATIONS

Fig. 1—TOUCH/PROXIMITY SWITCH can be used for touch-ON/touch-OFF control of a device or appliance or, with increased sensitivity, can be used in a proximity-operated intruder or burglar alarm.

sensitivity of the switch. If the switch tends to bounce at all, increase the value loaded in BC in line DBLCHK. I call a short time delay called TDM before each CVAL call to give the capacitor a little time to discharge; but if your application only calls CVAL occasionally, this is not necessay. If the touchplate is a fairly large piece of metal, the switch will trip just by coming near it (adjust the "minimum on value" for the best performance).

This type of proximity switch lends itself easily to security and burglar alarm applications. A single IC provides you with six inputs that could be sequentially polled by CVAL to indicate the status of all doors and windows. The metal plates would be easy to hide and difficult to defeat.
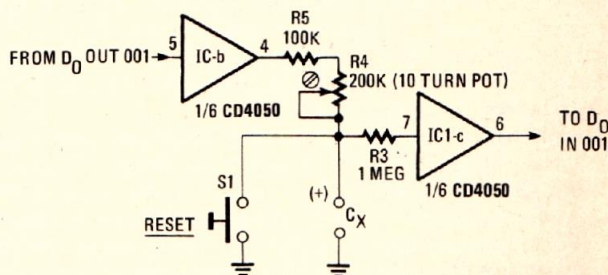
Fig. 2—A CAPACITANCE METER is formed when this interface is used with a microprocessor. The machine prints out capacitor values between 500 pF and 5 μF.

Capacitance meter

Figure 2 shows a circuit that, when driven by Listing III and CVAL, represents an extremely easy way to measure unknown

PARTS LIST

Resistors ¼ watt, 10% unless otherwise noted
R1, R3, R6—1 megohm
R2—470,000 ohms
R4—200,000 ohms, 10-turn trimmer potentiometer
R5—100,000 ohms
R7—4700 ohms
C1—200 pF, 10 volts, ceramic disc
C2—.033 μF, 10 volts, polystyrene
S1—normally open pushbutton switch
IC1—CD4050 CMOS non-inverting hex buffer

capacitances. The circuit uses one buffer to charge the unknown capacitance through the calibration potentiometer. The RESET pushbutton insures that large-value capacitors are totally discharged before each test. To calibrate the unit, use one or more good-quality close-tolerance capacitors in the range of 0.005 μF to 0.01 μF, and repeatedly run Listing III, while adjusting R4 until the routine prints the correct value of the capacitors. Listing III could be written in any BASIC that permits calling a machine-language program (calls CVAL in line 60), and then
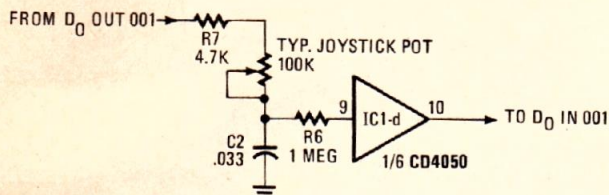

FROM D$_0$ OUT 001

R7 4.7K

TYP. JOYSTICK POT 100K

IC1-d

C2 .033

R6 1 MEG

1/6 CD4050

TO D$_0$ IN 001

Fig. 3—THE POSITION OF A JOYSTICK CONTROL is printed out in numbers from 10 to 250. When the joystick is operated by a servo, the printout can be a remote indicator.

```
                    LISTING III
                           ;remarks
   10 OUT 1, 0              ;OUTPUT 0 TO PORT 1
   20 PRINT "INSERT UNKNOWN CAPACITOR"
   30 PRINT "PUSH RESET FOR A SECOND"
   40 PRINT "NOW HIT RETURN TO TEST, N-RETURN TO
      QUIT"
   50 INPUT S$
   55 IF S$ = "N" THEN GOTO 100
   60 LET X = CALL (17408)  ;CALL MACHINE LANGUAGE
                           ;CVAL
   70 LET X = X*.0001       ;CONVERT TO MICROFARADS
   80 PRINT "CAPACITOR EQUALS ";X;" µF
   90 PRINT " "             ;DO SOME CARRIAGE
                           ;RETURNS
   91 PRINT " "
   92 PRINT " "
   95 GOTO 10               ;NEXT TEST
  100 END
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                    LISTING IV
                           ;remarks
   10 OUT 1,0               ;CLEAR PORT 1
   20 LET X = CALL(17408)   ;CALL CVAL
   30 PRINT X               ;SHOW VALUE OF JOYSTICK
                           ;POSITION
  -or-(30 PRINT TAB (X/8);"*") ;USING THIS FOR LINE 30
                           ; SHOWS AN *
                           ;CORRESPONDING
                           ; TO JOYSTICK POSITION
   40 GOTO 10
   50 END
```

allows assigning the value returned in register pair HL to a variable (X). The values shown are good for capacitors in the range of approximately 500 pF to 5 μF. Vary the size of the charging resistor to measure other capacitance ranges.

Joystick interface

The circuit shown in Fig. 3, when polled by CVAL, provides a simple way of digitizing the position of a joystick potentiometer. The values shown will cause CVAL to return with a number in HL from about 10 to 250, representing the position of the joystick. Listing IV prints these values for unit checkout. Substituting the alternate line 30 (shown) moves an asterisk back and forth across the display screen according to the position of the joystick potentiometer. Two of these circuits are required to obtain both the X and Y values from the joystick.

These circuits only scratch the surface of the possible applications for this technique. A 4 × 4 array of touchplates with four 4-input CMOS NOR gates to monitor row status and software drivers sequentially testing the columns could form an inexpensive touchswitch hexadecimal keyboard. Many types of sensors (temperature, pressure, etc.) can be used directly with these circuits, thus allowing you to monitor analog-type signals with a minimum of hassle. A little experimentation will yield a large number of nifty applications, while doing minimum damage to your pocketbook. And your computer will thank you for letting it hear from something other than a keyboard.   **R-E**

PIONEERS IN RADIO

Sir Jagadis Chundar Bose

FRED SHUNAMAN

JAGADIS CHUNDAR BOSE BEGAN HIS SCIENTIFIC career as a professor of physical science in Calcutta (where, as a native, he received two-thirds the pay of European professors with the same qualifications). Interested by Lodge's report on the work of Hertz (1894) he repeated all Hertz's experiments, working, as he said, "with none of those mechanical facilities at my disposal that every European and American scientist takes for granted."

He ran a meticulous series of tests on conherer materials, evaluating the sensitivity of practically all available metals. In these experiments, he discovered that the resistance of a coherer using potassium increased rather than decreased with the passage of an electric wave, thus questioning the validity of then-current coherer-action theories.

He invented an original coherer with spirals of fine wire, usually made of steel, laid in a slot cut in ebonite. The slot was terminated at each end with brass plugs—one fixed and the other adjustable with a screw. The spiral bits made about a thousand well-defined contacts with each other, claimed Bose, and these contacts could be adjusted with the single screw.

In 1895 at a lecture in Calcutta, Bose transmitted the newly discovered electric waves 75 feet to an adjoining room, tripping a relay that fired a pistol and blew up a small mine.

Possibly Bose's most important work was his demonstration to European scientists that Hertzian waves actually existed in the real world, not merely in scientific papers. He constructed a compact demonstration apparatus using a turntable. This made it possible to perform most of the experiments for which Hertz had needed a long hall. The equipment could be packed in a case only 60 centimeters long and 30 centimeters high and wide (or about 2 feet by 1 foot). Using this equipment he lectured to the Royal Society in London in January of 1897, in

Paris on March 9, and in Germany and in other European countries later.

In working with coherers, Bose noted that they became less sensitive with continuous use, but regained sensitivity if not used for a while. Extending his studies to plants, he became convinced that the boundaries between animal and vegetable life and nonlife were not as rigid as commonly believed. Official science was outraged at this "metaphysical" and "nonscientific" approach, and the Royal Society refused to print his papers for many years. He was regarded as a mystic and was ostracized by the scientific community. To this day, his name rarely appears in any work on electronics. A similar—if not as complete—a suppression appears to have taken place with respect to his quite extensive efforts in the field of biology. Scribner's Encyclopedia states: "Today, when biophysics is a generally recognized discipline"—his theories might not appear so controversial.   **R-E**